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Note on the Kinetic Energy Spectrum of Coastal Winds

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ABSTRACT—An examination of the spectrum of winds along the Oregon coast shows a major diurnal peak at a period of 24 hr and a small microscale peak at about 50 s. The 24-hr peak is thought to be associated with the diurnal variation of land–sea temperature difference.

1. INTRODUCTION

This study was conducted primarily to determine if the power density spectrum of coastal winds contained the same spectral gap, where there is very little eddy kinetic energy, as has been found in other localities (Van der Hoven 1957, Oort and Taylor 1969, Hwang 1970, Fiedler 1971). This gap is usually found between a microscale maximum of energy, occurring at frequencies near 30 cycles/hr or higher, and various maxima occurring from 0.08 to 0.01 cycle/hr (corresponding to periods of between 12 hr and several days). The gap appears to be centered somewhere between 6 cycles/hr and 1 cycle/hr.

The existence of an energy peak in the microscale region is well established (see Busch and Panofsky 1968 for a summary of recent data), and the frequency of the microscale maxima seems to be in the neighborhood of 1/60 cycle/hr. However, on the low-frequency side of the spectral gap, the periods at which relative maxima occur are not as well documented. Thus, Van der Hoven found maxima at 12 hr and about 4 days with no maximum at 24 hr. Oort and Taylor found several peaks in the spectrum at periods between 2 and 10 days and a strong peak at 24 hr; Fiedler's spectrum is similar. Hwang found a maximum at 4–6 days and a small peak at 36 hr but none at 24 hr. These spectra were all taken from different locations: Van der Hoven's at Brookhaven on Long Island, N.Y., from observations about 100 m above the surface, Oort and Taylor's from surface data at Caribou, Maine, Fiedler's from a 50-m mast near Munich, Germany, and Hwang's from surface data at Palmyra Island (5.8°N, 162.2°W) in the Pacific Ocean. Some of the differences among these spectra can certainly be ascribed to location as well as height of measurement. In this note we will present the results of our analysis of data taken on the west coast of the United States and compare the results with those of the authors mentioned above.

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2. SITE AND CLIMATE

Our site is located in South Beach, Oreg., on the south bank of the Yaquina River across from the town of Newport (44.6°N, 124°W). The wind speed and direction were measured with a 3-cup anemometer and twin-tail vane (NWS F102 and NWS F012, respectively) located on the beach. The sensors were mounted on a 9-m mast that sat atop a small mound. This location puts the sensor about 20 m above mean sea level. The ocean is about 200 m (depending on the state of the tide) west of the mast. To the north of the site are two rock jetties where the Yaquina River enters the Pacific Ocean. North of the jetties and south of the site, wide sand beaches extend for several miles in an approximately north–south direction. High bluffs are found behind the beach to the north and lower bluffs, to the south. The location of the sensors is such that a due-north wind is almost parallel to the shore and has an over-water trajectory.

In July and August, the Oregon coast is generally under the influence of the eastern Pacific subtropical High. This High produces north to northwest surface winds along the coast, which in turn produce intense upwelling of the ocean water. The near-shore surface temperature of the water can be as low as 7°C and usually does not exceed 12°C. The weather is usually clear, particularly in the afternoons, and little precipitation occurs; an inversion with a top near 1000 m dominates the weather.

A diurnal variation of wind speed can be detected in the coastal wind records, but it rarely leads to an offshore component of the wind; maximum speeds, therefore, occur in the afternoon and the minimum, at night. An apparent sea-breeze pattern is imposed on the northerly flow. Occasionally, a weak trough comes through from the west resulting in southwest winds and some precipitation.

During the period that we recorded the winds for this study (July 13–Aug. 7, 1970), the weather followed the pattern described above; most of the days had northerly winds. Only about 10 percent of the winds during the

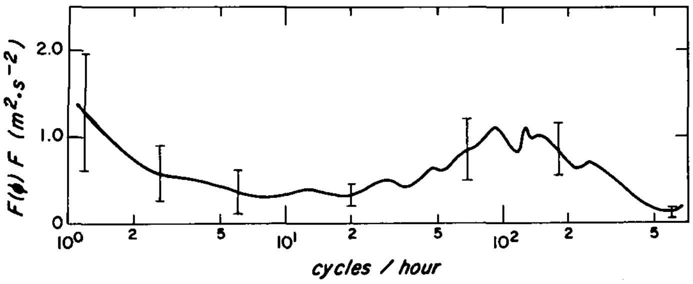

FIGURE 1.—Spectrum of wind speed from short-run data at South Beach, Oreg.

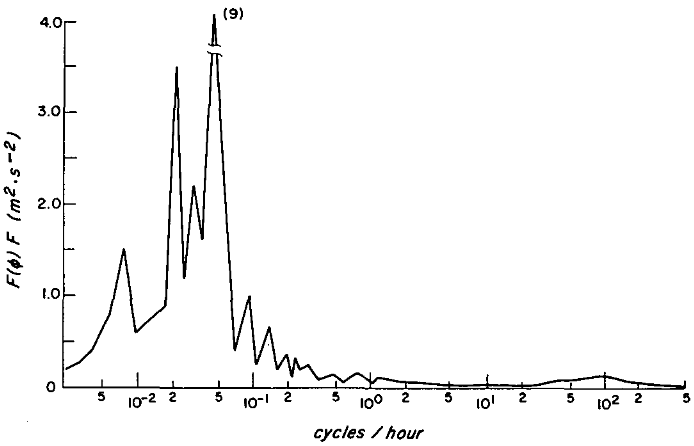

FIGURE 2.—Composite spectrum of surface wind speed at South Beach, Oreg.

study had an easterly component, and there were a few days influenced by trough passages that gave SW winds. Thus, our wind record is not only typical of coastal Oregon in the summer, but the air was very largely marine air moving onshore.

3. DATA REDUCTION AND ANALYSIS

The anemometer readout consists of a mark every time 1 mi of wind has passed the sensor. Special provisions can be made to record every 1/60 mi of wind passage. During the 25-day period, 18 short runs (of 1- to 3-hr duration) were recorded using the 1/60-mi interval. These consist of 1,024 data points (or about 17 mi of wind).

These short-run records were converted to a time series by estimating the amount of wind passing the sensor at 3-s intervals; this procedure gives a 3-s average wind speed. These 18 separate runs were all made during the daylight hours with the majority between 1200 and 1800 PDT. Of the 18 cases, four had southwest winds, one had northeast, one had northwest, and the rest had north. (The direction recording of the anemometer does not provide discrimination of more than eight directions.) The lowest average wind speed was 3 m/s and the highest about 9 m/s, with an overall average of 6.6 m/s for the short-period runs. The average wind speed over the entire period was about 4 m/s; therefore, the short-run data are biased toward higher wind speeds—a result consistent with their being taken in the daytime. The short-period records were used to deduce the energy spectrum between 51.2 min and 6 s. The entire 23-day record was used to obtain a record of 1,024 wind speeds averaged over 30-min intervals and treated in a similar manner. A more detailed description can be found in Frye (1972).

The transformation to wind speeds averaged over time intervals does filter some of the high-frequency energy from the record but should not affect our general conclusions. The fact that the sensor was not designed for very fast response probably resulted in some additional loss of high-frequency energy.

The transformed data were then treated with a fast-Fourier-transform technique to compute the Fourier coefficients, and these in turn were used to compute the spectra (Frye 1972). A band-averaging scheme was employed to obtain 46 spectral estimates for each of 1,024 data points. The 18 individual values were averaged, and the resulting spectrum is shown in figure 1. The vertical bars indicate the 95-percent confidence intervals of the computed means. The values of the maximum (at about 100 cycles/hr) and the minimum (near 10 cycles/hr) are lower than those found by Van der Hoven. While the seeming discrepancy may well lie in the recording system, it also seems likely that the aerodynamically smoother ocean would produce lower values. The frequency of the maximum (100 cycles/hr) is somewhat higher than those found by others (Busch and Panofsky 1968).

Figure 2 is the composite spectrum calculated over the whole range of observations. The striking feature of the spectrum is the peak at 24 hr (0.04 cycle/hr). The secondary peaks at 2 and 5 days probably came from the trough passages during the period. Other small secondary peaks are found at 0.08 and 0.16 cycle/hr.

The spectral gap as found by Van der Hoven is also present in this spectrum. The position of the gap is difficult to assess accurately, partly because the short-run section is composed of higher average wind speeds than the long-run portion. The minimum is located between 6 and 20 cycles/hr, which overlaps the range of 1.0 to 10 cycles/hr found by Van der Hoven.

4. DISCUSSION

Our spectrum is most readily compared with Hwang's because it was taken for roughly the same length of time and in somewhat similar shoreline exposures. (So few of our winds came from the land that they should be representative of the seaward conditions.) Our value of the microscale peak is slightly larger than Hwang's, and the value of our minimum is roughly comparable to his. We find some small energy at 2–7 days, but since the summer weather at this location has very little cyclonic activity, it is not surprising that our data show little energy beyond 2 days.

The major difference comes with the peak at 24 hr. Neither Hwang's spectrum nor Van der Hoven's shows any significant peak at this period, whereas ours, Oort and Taylor's, and Fiedler's show considerable energy there. Our value of about 9 $m^2 \cdot s^{-2}$ is actually a bit higher than most of Oort and Taylor's values, which generally ran from about 5–6 $m^2 \cdot s^{-2}$, although several of the spectra they present did show values as high as 9 $m^2 \cdot s^{-2}$.

Blackadar (1959) has explained the failure of Van der Hoven's spectrum to exhibit a peak at 24 hr on the basis of the elevation of his sensors. The sensors were high enough to be unaffected by the diurnal wind speed change due to the diurnal variation of stability. This explanation seems corroborated by Oort and Taylor's finding of a strong 24-hr peak in the surface wind spectrum. It does not explain the lack of such a peak in Hwang's spectrum, however, since his data were taken near the surface. Also, we do not feel the 24-hr peak in our spectrum comes from the daily cycle of strong and weak coupling of the surface winds to the upper winds through stability changes. The waters off Oregon in the summer are cool because of the upwelling. Surface water temperatures off Newport in July and August are typically 12°–13°C, which is cooler than the overlying air. Thus, the marine air is likely to be stable in the low levels almost all the time and little diurnal variation of stability would be found.

We feel our 24-hr peak is caused by the sea-breezelike situation found along the coast here. Normally, one would expect a sea-breeze–land-breeze regime to show a 12-hr period *in the speed;* but along the coast, the diurnal wind field is impressed on fairly steady gradient flow around the subtropical High and the result is a strong 24-hr (rather than a 12-hr) periodicity in the wind speed. (Furthermore, the cold surface waters may inhibit the development of a land breeze at night.) The small peaks at 12- and 6-hr periods may be due to occasional times when the sea breeze dominates.

We would suggest that Hwang's spectrum does not show a 24-hr peak because (1) the open ocean shows very little diurnal variation in surface temperature and hence there is little diurnal variation of stability, and (2) Palmyra Island (or atoll) is too small to develop much of a sea-breeze circulation, at least at the site he chose.

5. SUMMARY

The spectrum of coastal winds in summer along the Oregon coast exhibits a spectral gap between a small microscale peak at about 100 cycles/hr and a major diurnal peak at 24 hr. The 24-hr peak is thought to be caused by the diurnal variation of land–sea surface temperature difference rather than the diurnal variation of stability.

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